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THE UNIVERSITY OF ALBERTA

EFFECTS OF INTERFERENTIAL CURRENTS ON NERVE CONDUCTION VELOCITY

BY

LAURA J. FREEBAIRN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL THERAPY

EDMONTON, ALBERTA

FALL 1987

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Effects of Interferential Currents on Nerve Conduction Velocity submitted by Laura J. Freebairn in partial fulfillment of the requirements for the degree of Master of Science.

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(Supervisor)

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Date: April 22, 1987

DEDICATION

This thesis is dedicated to my parents who have suported my every venture. Thank you for your wisdom, your moral and financial support and your unfailing confidence in me.

ABSTRACT

The purpose of this study was to determine whether treatment with interferential currents had any effect on sensory or motor nerve conduction velocity and skin temperature. Interferential currents with frequencies of 0-20 Hz, 80-100 Hz and 0 Hz (control) were applied over the medial aspect of the dominant forearm using a flexible quadripolar electrode. Interferential stimulation of a high intensity (strong "pins and needles" sensation) was applied for a duration of 10 minutes. Orthodromic motor and antidromic sensory conduction measurements of the ulnar nerves of 18 healthy female subjects were completed at specific time intervals before and after treatment. Skin temperature data were also collected at set intervals before, during and after treatment. The results indicated that the application of interferential currents with frequencies of 0-20 Hz or 80-100 Hz for a period of 10 minutes, does not significantly alter sensory or motor nerve conduction velocity. Skin temperatures did increase significantly over time, but there was no significant difference in temperatures between treatment groups. The increased skin temperatures observed in this study were attributed to the insulating action of the interferential pad. The findings of the present study do not support the theory that the pain relieving action of interferential current therapy is due to decreased motor and sensory nerve conduction velocities.

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CHAPTER 1

THE PROBLEM

BACKGROUND TO THE PROBLEM

Interferential therapy is a relatively new physiotherapeutic modality.[1,2] Although it is frequently used clinically in the treatment of a variety of traumatic and pathological conditions,[1-5] there has been a lack of published research examining the physiological effects of this modality.

One of the clinically important physiological effects of interferential is claimed to be analgesia.[1-6] It is thought that the analgesic effect is strongest in the 80 to 100 Hz range.[2-6] The mechanism of pain relief by interferential is not well understood and several theories have been proposed, most of which involve spinal, rather than peripheral mechanisms. These theories of pain relief are: 1) activation of the pain-gating mechanism, 2) stimulation of the descending pain suppression system and endogenous opiate mechanisms, 3) a direct block of nociceptive fiber activity, 4) removal (from the damaged area) of substances which stimulate pain nerve endings, and 5) a placebo effect.[2,6,8] To date there has been no published research evaluating these theories.

Another possible mechanism of pain relief with interferential therapy might be decreased sensory and motor nerve conduction velocity. Griffin[9] postulated such a mechanism as being responsible for the pain relieving action of ultrasound. According to Griffin[9], if sensory fiber impulse propagation decreases, relief of pain may occur due to decreased

stimulation of the central nervous system. Conversely, decreased motor fiber impulse propagation may relieve pain and muscle spasm by decreasing the tension in the muscle fibers supplied by the treated nerve.

In view of the frequent clinical use of interferential therapy, it is important to understand its physiological effects, and in particular its effects on underlying nervous tissue. The present study examined the effects of interferential therapy using frequency ranges of 0 to 20 Hz and 80 to 100 Hz, on ulnar sensory and motor nerve conduction velocities.

PRIMARY RESEARCH HYPOTHESES

H_1: There is a decrease in motor nerve conduction velocity (NCV) following the application of interferential current (IFC) in the 80-100 Hz frequency range.

H_2: There is a decrease in sensory NCV following the application of IFC in the 80-100 Hz frequency range.

H_3: There is no change in motor NCV following the application of IFC in the 0-20 Hz frequency range.

H_4: There is no change in sensory NCV following the application of interferential therapy in the 0-20 Hz frequency range.

H_5: There is no change in skin temperature following the application of IFC in the 80-100 Hz frequency range.

H_6: There is no change in skin temperature following the application of IFC in the 0-20 Hz frequency range.

OBJECTIVES

The objective of the present investigation was:

To examine the effects of specific interferential therapy frequencies (0-20 Hz and 80-100 Hz) given at a therapeutic dosage on:

i) motor nerve conduction velocity of the ulnar nerve, and

ii) sensory nerve conduction velocity of the ulnar nerve.

iii) skin temperature in the treatment area.

OPERATIONAL DEFINITIONS

1. Interferential current: IFC produces a low frequency current (between 0 and 100 Hz) within the body as a result of the interaction of two medium frequency currents (4000 and 3900 Hz). One current always remains at 4000 Hz while the other may be altered between 3900 and 4000 Hz, (4000 and 4100 Hz in some interferential units).[2,3,5] The interferential current has a sinusoidal waveform and the current is without polar effects.[5] The intensity of the current may be varied and is measured in milliamps.[2,5]

2. Beat frequency: The difference between the two medium frequency currents is termed the beat frequency (for example: 4000 minus 3900 Hz equals a beat frequency of 100 Hz). The beat frequency may be altered between 0 and 100 Hz and may be constant or rhythmical.[2] In the constant mode, the difference between the two medium frequency currents remains constant (for example: 50 Hz for the duration of the treatment). In the rhythmical mode,

the difference between the two medium frequency currents changes rhythmically (for example: 80 to 100 Hz and back to 80 Hz). The duration of the rhythmical cycle is selected prior to treatment.[2]

3. Vector Sweep: This type of sweep involves rotation of the static interferential field through an angle of approximately 45 degrees and back again.[2,10] Movement of the interferential field is produced by rhythmically unbalancing the interfering currents to change the position of the areas of maximum stimulation. Use of the "rotating vector sweep" allows a larger area of tissue to be influenced by the higher intensities of the interferential field than with the static field.[2] The concept of the static IFC field versus the field covered by the rotating vector sweep is illustrated in Figures I-1 and I-2 respectively.
4. Nerve conduction velocity: NCV is determined as the distance a nerve impulse travels along a nerve, per unit time (Distance/Time). Nerve conduction velocity is expressed in meters per second.[11]
5. Stimulus artifact: A deflection observed on an oscilloscope or oscilloscope trace which occurs as a result of stimulating a nerve and represents the initiation of a nerve impulse[11] (Figure I-3).
6. Latency: The time between the stimulation artifact observed on an oscilloscope or oscilloscope trace, and the observed deflection of the muscle action potential.[11] It is a direct function of the nerve segment length between stimulation and recording points.[12] Latency is expressed in milliseconds[11] (Figure I-3).

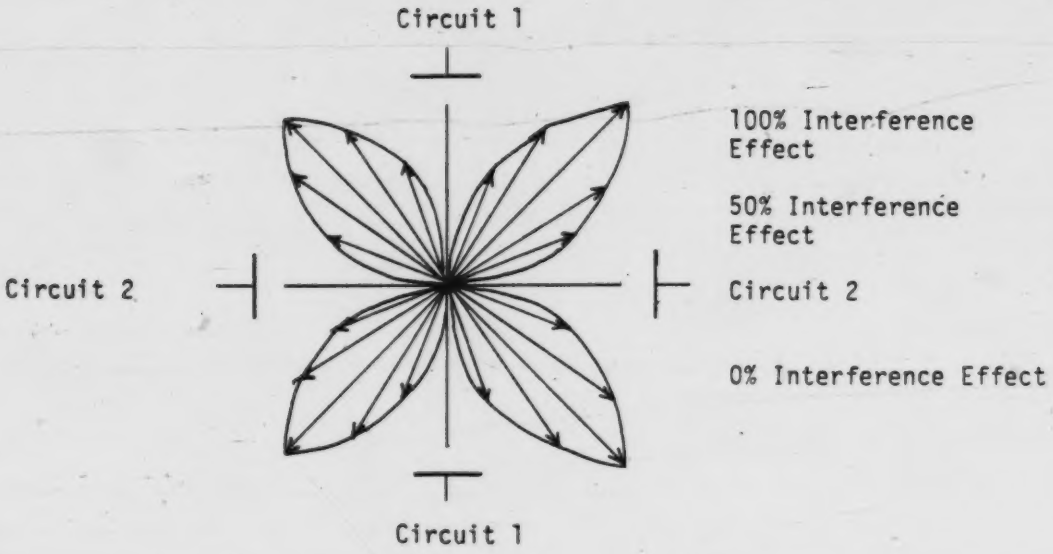

Figure I-1. The static interferential field. The area directly under the electrodes apparently receives little or no interference effect in the static field.2

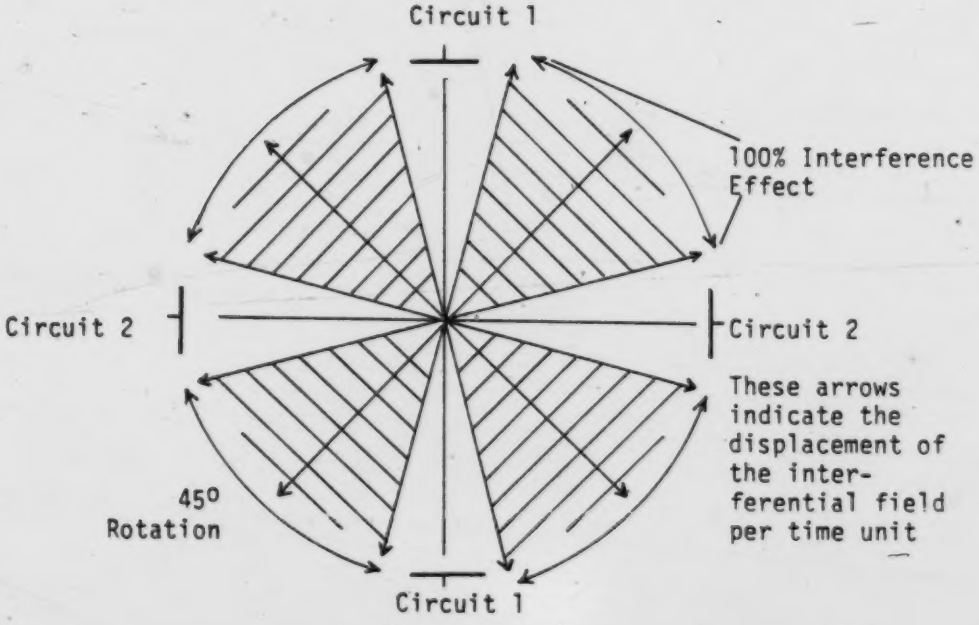

Figure I-2. The Interferential rotating vector sweep. Periodic shifting of interferential current vectors into directions of lower modulation allows larger treatment areas to be covered by 100% interference effects.[2]

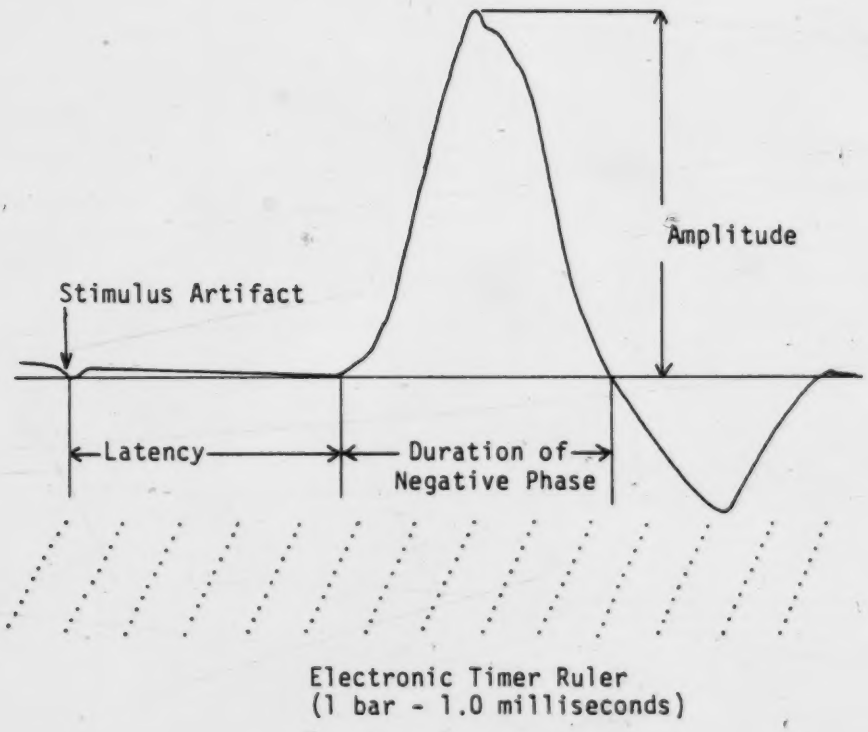

FIGURE I-3. Evoked muscle action potential[11,13]

7. Supramaximal response: This response is observed on an oscilloscope or oscilloscope trace when no further increase in amplitude or decrease in latency are apparent with slight increases in stimulus intensity.[11]

8. Antidromic technique: This technique consists of stimulating a nerve, in this case a sensory nerve, proximal to the sensory organ (finger) such that the nervous impulse runs along the sensory nerve fiber distally and the impulse is recorded distal to the stimulus. This direction of conduction in the sensory nerve is reverse to the normal flow. Using the antidromic technique for sensory nerve conduction tests presents the advantage of producing a larger nerve action potential with less intensity of current.[11,12]

9. Orthodromic technique: This technique consists of stimulating a nerve, in this case a motor nerve, proximal to the recording electrodes so that the nerve impulse travels distally. This is the normal direction of nerve conduction in motor nerves.[1]

DELIMITATIONS

1. Only normal females between 18 and 40 years were tested because of differences in motor NCV between the sexes and age related changes in conduction velocities reported in the literature.[11,14]

2. Only the ulnar nerve on the dominant arm was tested since it has been reported that subjects exhibit a higher NCV on the dominant side than on the nondominant side.[14]

3. The interferential treatment frequencies were limited to 0 to 20 Hz and 80 to 100 Hz because these are the IFC ranges most commonly cited for pain relief.[2,16] Additionally, choosing these frequency ranges allowed comparisons of the effects of the low and the high IFC frequencies on NCV.
4. Treatment time was limited to 10 minutes since this is the time period frequently used in the clinical setting.[1-3]

LIMITATIONS

1. Due to individual differences in tolerance to electrical stimulation, the intensity of stimulation varied. Subjectively, a high intensity of "strong pins and needles" varied between subjects. (Mean intensity for 0-20 Hz was 7.6 mA, mean intensity for 80-100 Hz was 8.1 mA)
2. The distance from the tip of the olecranon to the interferential electrode pad remained constant at each testing session. However, the relation between the ulnar nerve and interferential electrodes may have varied slightly as the result of the investigators inability to precisely duplicate electrode position on the forearm.
3. Using the antidromic technique of recording sensory nerve potentials, there is a possibility of recording intrinsic muscle potentials in some cases.[16]
4. Determination of motor nerve conduction velocity was based on selection of the point of upward deflection of the baseline. Consistency in calculation of motor nerve conduction velocity was therefore limited by the ability of the investigator to

consistently select the point of initial deflection from the baseline.

5. Determination of sensory nerve conduction velocity was based on selection of the peak deflection. Consistency in calculation of sensory nerve conduction velocity was therefore limited by the ability of the investigator to consistently select the peak deflection.

CHAPTER II

LITERATURE REVIEW

Interferential current (IFC) therapy has been in use for almost 30 years, although it has only recently gained international popularity.[2] The concept of medium frequency interferential currents was originally developed by Dr. Hans Nemec in the 1950's, as a method of producing low frequency alternating currents in the body tissues without the problem of high skin resistance.[2]

SKIN RESISTANCE

Normal human skin has a high resistance to low frequency currents.[2,5,16] According to De Domenico,[2] skin resistance to a current of 50 Hz is approximately 3000 ohms per 100 cm^2. High voltages are required, therefore, to overcome the skin resistance and still stimulate excitable tissue such as nerve and muscle.[2,16] Such high voltages produce uncomfortable cutaneous sensations which patients have difficulty tolerating.[2] When the frequency of an alternating current is increased the skin resistance decreases, thereby lessening the sensory discomfort experienced by the patient.[2,16] At 4000 Hz for example, skin resistance may be as low as 40 ohms per 100 cm^2.[16]

High frequency currents such as short wave or microwave diathermy have mainly thermal effects and are too high in frequency to stimulate nerve or muscle.[16] Medium frequency currents overcome the problems of skin resistance and thermal effects. However, the medium frequency currents are still well above the biological frequency range for

stimulation of muscle.[2] The stimulation of excitable tissue is only possible at relatively low frequencies, and frequencies of up to approximately 100 Hz are generally used for treatment with most interferential units.[22,5]

According to Savage,[5] skin resistance is at a minimum at frequencies of approximately 4000 Hz. Therefore, to overcome the problem of skin resistance, two medium frequency curents of between 4000 Hz and 4100 Hz are superimposed to endogenously generate low frequency currents.[2,25,16] This is the basis of interferential current therapy.

CURRENT FORMAT

With IFC therapy, the current in one circuit is fixed at approximately 4000 Hz while the current in the second circuit is variable and usually ranges between 4000 to 4100 Hz.[2,5,16,17] An interference effect from the two currents occurs within the patient's tissues, thereby generating a low frequency current which, depending on the setting of the second circuit, may range between 1 and 100 Hz.[2,17] In the area where the two currents cross, or are "heterodyned," the intensity of the combined currents will increase and decrease rhythmically[2,5,16] (see figure II-1). The "beat frequency" is the number of times per second that the current rises to its maximum intensity and falls to its minimum value.[2,16] The beat frequency in numerical terms is the difference between the two medium frequency currents. If the incoming frequencies are 4000 Hz and 4100 Hz, the resultant beat frequency is 100 Hz.

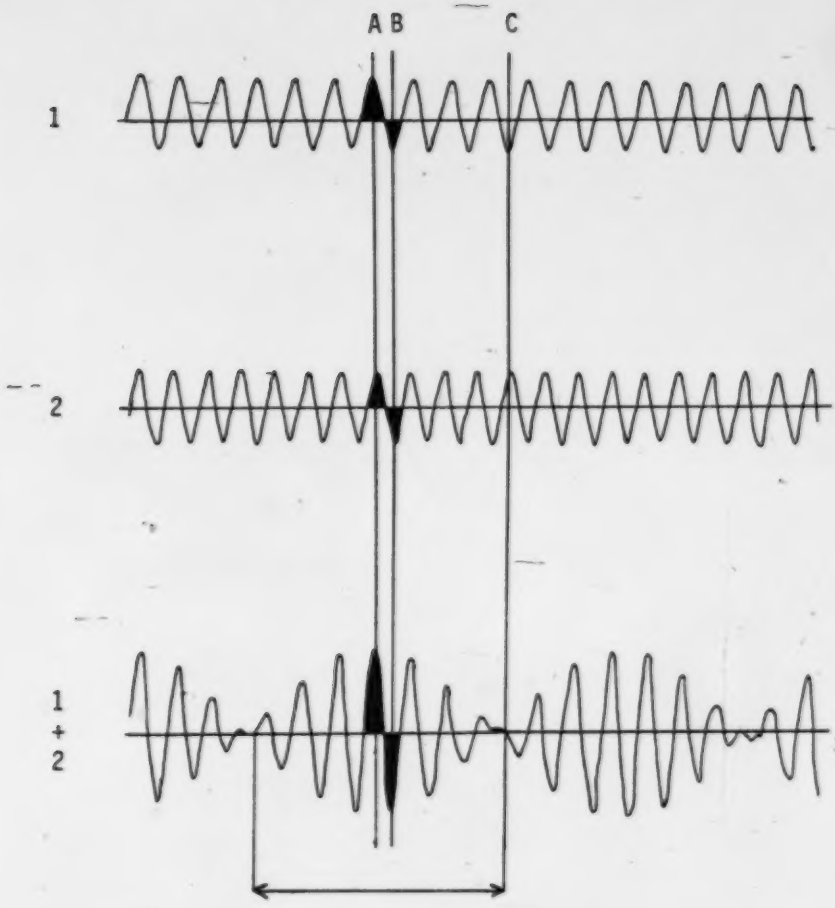

Figure II-1. Heterodyned currents. The two currents illustrated in 1 and 2 are of slightly different frequencies. At certain points the two phases will match identically (A and B), resulting in a summation and overall increase in amplitude. At point C the two currents are equal and opposite cancelling each other out. The "beat" frequency is the number of times per second that the current rises to its maximum intensity and falls to its minimum.[2,5]

INTERFERENTIAL FIELD DISTRIBUTION

Discrepancies exist in the literature regarding the field of distribution of interferential currents. De Domenico[2] suggested that the maximum interference effect occurs in a cloverleaf distribution as illustrated in figure I-1. One interferential manufacturers' manual illustrates certain areas of the field as having no interference effect[10] (figure I-1). According to Deller,[18] however, interference currents will occur at all points in the area treated and in all directions, although the currents will vary in magnitude. Several authors agree that since body tissues are not homogeneous, current flow will not be uniform throughout the treatment area.[2,18]

Treffene [19] investigated the field distribution of interferential currents in a homogeneous medium (water). In contrast to other authors' predictions,[10,20] Treffene[19] observed that a strong beating signal occurred at points along the lines joining the electrodes.

To date, few published studies have clearly established the interferential field distribution in human tissues. Most descriptions of the field have been based on calculations from vector diagrams, assuming homogeneous mediums.[18,19] Meyer-Waarden et al[21] suggested that the problem of representing electric fields in inhomogeneous biological media could be solved by considering inhomogeneous tissues such as subcutaneous fat, fascia, muscle, blood vessels, cortical tissue and tendons, as homogeneous in themselves and only showing corresponding surface charges at the interfaces.

Hansjurgens and Meyer-Waarden[22] calculated electric potentials in an inhomogeneous model, including skin, muscle, bone tissues, and a

bone cleft, to illustrate the distribution field of static and dynamic interference currents. A limitation with their method, however, was that it represented electrical fields on a plane surface, whereas biological tissues occupy three dimensions.

De Domenico[2] suggested that one of the problems associated with conventional interferential therapy is its two dimensional field. Several authors have suggested that stereodynamic interferential therapy using three medium frequency currents may have a more widespread effect than conventional IFC since the body tissues occupy three dimensions.[2,20] There is no substantial evidence, however, regarding the effectiveness of stereodynamic currents in comparison with conventional interferential currents.

PHYSIOLOGICAL EFFECTS

In normal tissue, cell membranes undergo transient alterations in permeability when functioning.[23] This change in permeability allows the rapid passage of ions across the cell membranes and it is this flow of ions that constitutes an electrical current.[23] The application of an external electric field can cause ionic currents to flow in excitable tissue (ie. nerve and muscle).[5] According to several authors, each type of excitable tissue has an optimum frequency at which the maximum response will be elicited.[2,5] Examples of optimum frequencies cited from the literature are listed below:

0-10 Hz, muscle (unstriated)[1-3,5]

0-30 Hz, small diameter nerve fibers (not specified whether sensory or motor nerve fibers)[2]

10-50 Hz, motor nerves[5,16]

80-110 Hz, sensory nerves[5,16]

80-100 Hz, depression of sympathetic nerves,[10]

0-5 Hz, stimulation of sympathetic nerves [5,10]

10-150 Hz, parasympathetic nerves[5]

The physiological effects of interferential currents depend primarily upon the frequency range chosen.[2] Wadsworth and Chanmugam[16] suggested that other factors such as the intensity of current used, accuracy of electrode placement, calibration of the circuits, potency of circulation and neurological function, use of constant or rhythmic frequency swings, and accurate localization of the lesion also play roles in determining the physiological effects of interferential current therapy.

Review of the literature revealed a number of claimed physiological effects of IFC therapy which are summarized as follows:

1. Stimulation of cellular processes[2]
2. Analgesia[2]
3. Regression of pathological calcium deposits [24]
4. Vasodilation and hyperemization[25]
5. Antispasmodic action (relaxes vascular spasm)[26]
6. Stimulation of acetylcholine production[26]
7. Activates regeneration of injured nerves[26]
8. Promotion of endosteal and periosteal callus formation in fractures[27]
9. Stimulation of the proliferation of fibroblasts[28]
10. Decreased peripheral motoneuron conduction velocity[29,30]

Table I-1 summarizes the therapeutic uses of interferential current therapy.

Table I-1. Therapeutic uses of interferential current therapy.

THERAPEUTIC USE	SUGGESTED IFC FREQUENCY
Pain relief	100 Hz[1,3,4] 90-100 Hz[3,16] 100-130[5], 80-100z[2] 1-20 Hz[2], 0-100 Hz[24]
Control edema:	0-100 Hz[1]
Expediate resolution of hematomas:	0-100 Hz[24]
Decrease incontinence and urinary frequency:	0-100 Hz[32,33], 0-10 Hz[1]
Facilitate healing in damaged tissues:	1-100 Hz[2]
Stimulation of callus formation in fractures:	100 Hz[27]
Activate regeneration of injured nerves:	0-100 Hz[26]
Intermittent claudication:	0-100 Hz[34]
Regression of calcium deposits:	0-100 Hz[2]
Inflammatory diseases of female genital organs:	100 Hz[25]
Endarteritis obligerans:	1-100 Hz[35]
Detrusor hyperreflexia in Multiple Sclerosis:	0-100 Hz[36]
Muscle re-education:	40-80 Hz[37]
Relief of classical migraine symptoms:	90-100 Hz[38]

INTERFERENTIAL CURRENT INDUCED ANALGESIA

A frequent claim in the literature is that IFC has marked analgesic effects.[1,2,5,6,16,31] De Domenico[2,6] proposed a number of possible mechanisms by which IFC relieves pain. These theories are:

i) activation of "pain-gating" mechanisms,

ii) stimulation of the descending pain suppression system and endogenous opiate mechanisms,

iii) a physiological "block" of nociceptive input,

iv) removal of the substances which stimulate pain nerve endings from within the damaged area, and

v) a placebo effect.

According to Belcher,[4] test results from the Institute for Research in Rheumatic Disease (Baden, Austria) indicate that "anoxaemic pain is affected considerably following interferential therapy." Belcher[4] did not elaborate on this statement, and the treatment regimen was not reported. Ganne[1] questioned whether the relief of causalgia and neuralgia type pains may be due to the effect of IFC on blood supply to the relevant nerves through release of sympathetic tone. Ganne[1] also postulated that the analgesic effects of IFC my be achieved by stimulating the large diameter nerve fibers as described in Melzack and Wall's[39] "pain-gate" hypothesis.

Wadsworth and Chanmugam[16] also suggested that the analgesic action of IFC may be related to the theory of large fibre stimulation. They reported that IFC pulses can block pain pathways by acting on the large 'A' alpha fibres, inhibiting pain at the spinal level through presynaptic inhibitory mechanisms. Wadsworth and Chanmugam[16] also

theorized that minimal stimulation of large diameter fibers causes a mild tingling sensation, which interferes with the perception of pain.

Another theory explaining the analgesic action of IFC suggested that interferential currents may alter the local distribution of ions.[16] Wadsworth and Chanmugam[16] speculated that using medium frequency currents (4000 Hz), causes repeated stimulation within the refractory period of nerve. As a consequence, no further excitation of the nerve can occur which causes rapid fatigue of the cutaneous pain receptors.[16]

Szehi and David[20] suggested that alleviation of pain using IFC occurs by changing the excitation pattern of the nerve fibers and by reducing the liberation of pain-producing substances (for example: prostaglandin, bradykinin and histamine) by damaged cells.

One possible mechanism of pain relief with IFC not discussed in the literature, is the slowing of peripheral nerve conduction velocity. Interferential frequencies between 80 and 100 Hz are apparently the most effective for pain relief.[3,16,26] Perhaps these frequencies (of 80 to 100 Hz) interfere with normal ion flow, altering membrane permeability, and causing a slowing of peripheral nerve conduction. If sensory NCV decreases, relief of pain would result from less stimulation of the central nervous system.[9] If motor NCV slows, relief of pain would be the result of less muscle tension and a decrease in muscle spasm.[9]

Although there are numerous theories regarding the pain relieving mechanism of interferential therapy, there is little scientific evidence to support these hypotheses.

CONTRAINDICATIONS

According to several authors, there are comparatively few absolute contra-indications to IFC.[2,5] Most authors agree that direct stimulation of malignant tumors is contra-indicated,[1,2,5,16] although it has not been proven that IFC has an accelerating effect on malignancies.[5] Several authors have suggested, however, that referred pain from cancer may be treated.[1,2,5,10] Patients with arterial disease, deep vein thrombosis, or thrombo-phlebitis should not be treated with IFC since the stimulatory effect of IFC may dislodge an embolus, or may increase the inflammation of the phlebitis.[16] One author suggested that the effect of interferential current is on the platelets and would tend to spread a clot with possible fatal results in a patients with coronary thrombosis.[5]

Savage[5] postulated that interferential currents produce chemical changes in the blood, leading to alterations in clotting time. Savage[5] concluded that interferential treatments should not be given to patients taking anticoagulants since IFC would render these medications ineffective.

The effect of IFC on bacteria is uncertain,[5] however, most authors advised against treating bacterial infections.[1,2,5,16] Wadsworth and Chanmugam[16] hypothesized that infections may spread or be excerbated by the stimulatory effect of the currents.

Pregnancy is another commonly cited contraindication to IFC since the effect of IFC on the developing fetus is apparently unknown.[1,2,10,16] Wadsworth and Chanmugam[16] suggested that while it is not safe to treat directly over a pregnant uterus, cases of sacro-iliac

strain during pregnancy may be effectively treated with IFC, provided the field is superficially placed over the sacro-iliac ligaments.

Other suggested contraindications to IFC include; patients with pacemakers,[2,5,10,16] particularly ventricular inhibited varieties,[2] patients with severe hypotension or hypertension,[2] treatment in the area of dermatological conditions,[2,10,16] treatment in regions where hemorrhage is a danger[1,2,10,16] and treatment within 2 to 3 metres of short wave units and other electrotherapy equipment.[40]

EFFECTS OF ELECTRICAL MODALITIES ON NERVE CONDUCTION

In contrast to other electrical modalities such as ultrasound, short wave diathermy and infrared lasers, there has been limited investigation of the effects of IFC on underlying nerve tissue. Studies examining the effects of ultrasound on sensory and motor nerve conduction velocity are numerous.[41-50] In 1966, Griffin[9] suggested that reduced NCV might be the mechanism of pain relief with ultrasound. Several investigators have provided evidence to support Griffin's hypothesis,[43-45,48] however, more recent studies have demonstrated increased sensory and motor nerve conduction rates to be associated with ultrasound.[41,42,46,47,50]

Kramer [41] observed that sensory nerve conduction velocity (ulnar nerve) significantly increased following ultrasound (frequency of 870 KHz) at 1.5, 2.0 and 2.5 W/cm^2. Increased sensory nerve conduction velocities were attributed to the thermal heating effects of ultrasound. Another study by Kramer[42] demonstrated increased ulnar motor nerve conduction velocity with all clinical intensities of ultrasound. These results are in contrast to previous studies which

demonstrated decreased velocities at intermediate intensities of ultrasound.[43,44] Kramer[42] attributed the discrepencies between the studies to ultrasound application techniques and differences in the areas treated. Rennie[50] also reported significant increases in both sensory and motor nerve conduction velocities following application of ultrasound at frequencies of 0.75, 1.5 and 3.0 MHz.

Short wave diathermy (frequency of 27 MHz) has been reported to cause increased motor nerve conduction velocity.[49,51] Claveau[49] postulated that increases in subcutaneous tissue temperature brought about by short wave diathermy, would cause a heating effect on motor nerves and therefore increased conduction velocity of the same.

A study by Greathouse et al[52] examined the effects of infrared laser, at a frequency of 73 Hz, on sensory nerve conduction. Results from this study indicated that infrared laser radiation treatment has no significant effect on sensory nerve conduction.

Literature concerning the effects of interferential current on motor or sensory nerve conduction velocity is limited. Belcher[4] reported no significant change in motor conduction velocities of either the median or ulnar nerve following interferential therapy. The frequency used in the study was 0 to 100 Hz (rhythmic) for 15 minutes at a grade II dose. The author did not specify what a grade II dose was. Suction electrodes were placed on the anterior and posterior aspects of subjects' right shoulder joint and peripherally on the anterior and posterior aspects of the wrist. Technique of recording conduction velocity was not reported by the author, and there was apparently no control group.

In contast to Belcher's findings, a study by Rehacek et al[29] reported decreased motor nerve conduction velocities of the peroneal nerve following stimulation of the lower leg with rhythmic interferential currents of 0 to 100 Hz. The current intensity used was 20 mA (± 2mA) for 15 minutes. A subsequent study by Rehacek et al[30] also reported decreased motor conduction velocities following 15 minutes treatments with intereferential currents of 0 to 10 Hz. Rehacek et al[29,30] used the same application techniques in both studies.

Differences in IFC application techniques may in part account for the discrepancy between Belcher's[4] findings and those reported by Rehacek et al[29]. Belcher[24] used suction electrodes spanning a very large area (shoulder to wrist), while Rehacek et al[29] treated a much smaller region. Additionally, it is unclear what current intensity Belcher used on her subjects.

Previous investigations of the effects of IFC on motor NCV have not attempted to monitor tissue temperatures.[4,29,30] Temperature directly affects conduction velocity of peripheral nerves in humans and is therefore an important variable when examining the effects of IFC on NCV.[12] Stone[12] suggested measuring skin temperature during the testing period since temperature fluctuations could be a confounding variable when measuring nerve conduction velocities.

NERVE CONDUCTION VELOCITY

There are slight discrepancies between investigators as to the normal motor conduction velocity values of the ulnar nerve. Johnson and Olsen [53] reported mean readings of 55.1 M/Sec (± 6.4) for ulnar motor

nerve conduction velocity. Abramson et al[51] reported mean motor conduction velocities of 58.7 M/Sec (± 4.0) for the ulnar nerve, while Melvin et al[54] found mean values of 57.0 M/Sec (± 4.7).

Normal values for sensory conduction velocity of the ulnar nerve range fom 56.8 M/Sec (± 4.3) to 59.5 M/Sec (± 4.0).[54] Melvin et al[54], found no significant differences between orthodromic and antidromic conduction velocities of the ulnar nerve.

CONCLUSION

Despite the frequent clinical use of interferential current therapy, there have been few studies examining its physiological effects, in particular, its effect on underlying nerves. Review of the literature has revealed no studies which have examined the effects of interferential currents on sensory nerve conduction velocity. Decreased peripheral nerve conduction velocities may in part account for the pain relieving action of IFC.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS

Eighteen informed female volunteers with no history of neurological disorders served as subjects for this study. The age of subjects ranged from 19 to 37 years (mean age 25.8 years ± 5.4 years). This investigation was limited to females due to reported differences in motor nerve conduction velocities between the sexes (faster on average in the female than the male).[14] The age range of 16 to 40 years was chosen to eliminate age as a factor affecting motor and sensory nerve conduction velocities. It has been reported that sensory nerve conduction decreases with increasing age from 40 to 65 years of age[55] and motor nerve conduction velocity decreases after the sixth decade.[56,57]

All subjects reported no history of major ulnar nerve trauma, diseases of the nervous system, fractures or dislocations of the elbow of the dominant arm or other conditions which could modify ulnar motor or sensory nerve conduction velocity. Additionally, no subjects reported having any of the conditions listed as contraindications to treatment with IFC.

All subjects were given a verbal explanation of the treatment and testing procedures. Subjects retained an information sheet regarding the study and signed an Informed Consent Form prior to participating in the study (see Appendix A).

Although there is no information in the literature regarding the duration of effects of interferential therapy, a minimum of 24 hours was allowed between testing sessions.

POSITIONING

Treatments and testing were performed on the dominant arm with the subject in a supine position. The dominant arm was tested in order to exclude any variation of nerve conduction velocity which may have occurred between the dominant and non-dominant arm.[14] The test arm was positioned in approximately 70 degrees of shoulder abduction, 50 to 70 degrees shoulder external rotation (depending on the subjects active range of shoulder external rotation), 30 degrees horizontal adduction of the shoulder, 90 degrees elbow flexion and approximately 45 degrees of forearm pronation[13] (Plate III-1). This position allowed easy access to the ulnar nerve during stimulation without putting undue stretch on the nerve.[13] Pillows and towelling were used to maintain the arm and forearm in position during treatment and testing.

INSTRUMENTATION

1. Electromyograph: A TECA electromyograph, Model TE-42* (Plate III-2) was used to perform the motor and sensory nerve conduction studies on the proximal forearm segment of the ulnar nerve. The supramaximal stimulus delivered with the TE-42 stimulator* was a rectangular pulse of 0.1 ms duration, delivered at a rate of two per

* TECA Corp., Pleasantville, NY 10570, USA

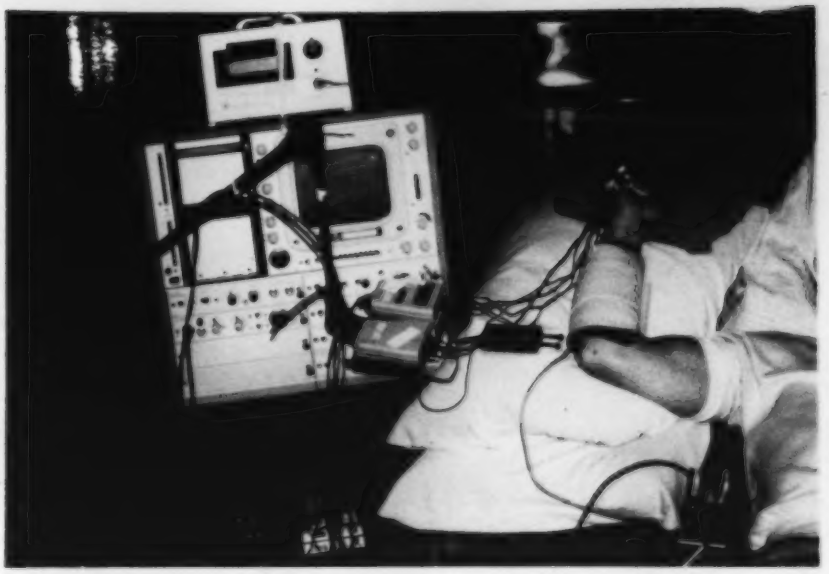

PLATE III-1. Position of subject during treatment and testing sessions.

second. The frequency response of the amplifier for motor and sensory nerve conduction testing was 1.6 and 3,200 Hz and 32 and 1600 Hz respectively.

Permanent recordings from the electromyogaph were taken on KODAK Linagraph direct print paper.*

2. Interferential Unit: The interferential unit used in this study was a Vectordyne 2+, which operated at a maximum of 4000 Hz[10] (Plate III-2). The current was sinusoidal, with a maximum patient current output in each circuit of 60 mA.[10] The interferential unit was checked with a frequency counter for accuracy of the actual frequency output (see Appendix B).

3. Digital Thermometer: Cutaneous temperature of the test forearm was recorded from a digital thermometer, YSI Model 49TA**. The digital thermometer had been calibrated for temperature conversion from a chemical thermometer (see Appendix B).

4. Timer: All treatments during the study were timed using a Gra-lab timer, model 171.

PROCEDURES

1. Testing: Each subject was assigned to one of the six treatment sequences as illustrated in Table III-1. By using all possible sequences of applying three treatment modalities, control for treatment

* EASTMAN KODAK CO., Rochester, NY 14650, USA

\+ Medelco Ltd., 4478 Chesswood drive, Downsview Ont., M3J 2B9

** YSI Model 49TA Digital Thermometer, Yellow Springs Instrument Comp., Yellow Srpings, OH 45387, USA

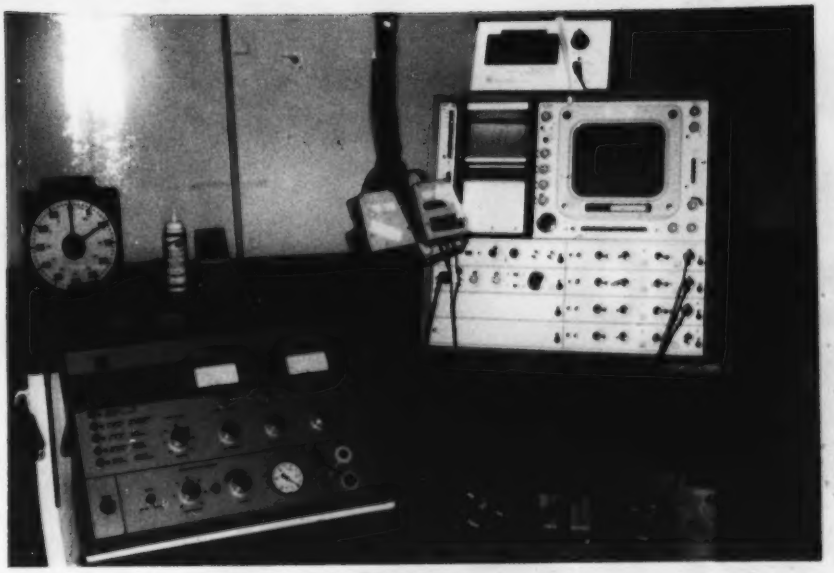

PLATE III-2.—Equipment used in the study.

TABLE III-1. Treatment sequences assigned to subjects for the three testing sessions.

SEQUENCE	SUBJECT		
1. Control, 0-20 Hz, 80-100 Hz	1	7	13
2. 0-20 Hz, 80-100 Hz, Control	2	8	14
3. Control, 80-100 Hz, 0-20 Hz	3	9	15
4. 0-20 Hz, Control, 80-100 Hz	4	10	16
5. 80-100 Hz, 0-20 Hz, Control	5	11	17
6. 80-100 Hz, Control, 0-20 Hz	6	12	18

effect and treatment order was achieved.[58] Subjects were not informed what treatment sequence they would be receiving.

Temperature of the testing area was maintained at an average of 25.6 degrees celcius ± 0.7 degress celcius, in order to minimize any effect that room temperature might have on nerve conduction velocity.[11,59,60] Subjects were instructed to limit strenuous physical activities for two hours prior to their testing time to minimize variations in body temperatures caused by the effects of exercise.[60]

Each subject was positioned in supine lying with the test arm exposed from the mid-arm distally. The ulnar aspect of the hand and fifth finger were prepared by lightly abrading with sand paper and cleaning the skin with isopropyl alcohol. This preparation allowed better electrode contact and lower skin resistance.[11] Transmission gel* was applied on the surface electrodes (recording and ground), to ensure good electrical contact with the skin.[11] The motor recording electrodes were surface discs, 8mm in diameter, mounted in a wooden bar so that interelectrode distances were contant (3cm center to center). Motor recording electrodes were positioned with the cathode over the center of the abductor digiti minimi muscle belly and the anode positioned over the tendon of abductor digiti minimi at the metacarpophalangeal (MCP) joint (Figure III-1). A ground electrode was applied to the dorsum of the hand. These electrode placements allowed motor nerve conduction to be performed orthodromically.[11]

* Aquasonic 100, Parker Laboratories Orange, NJ, 07050, USA

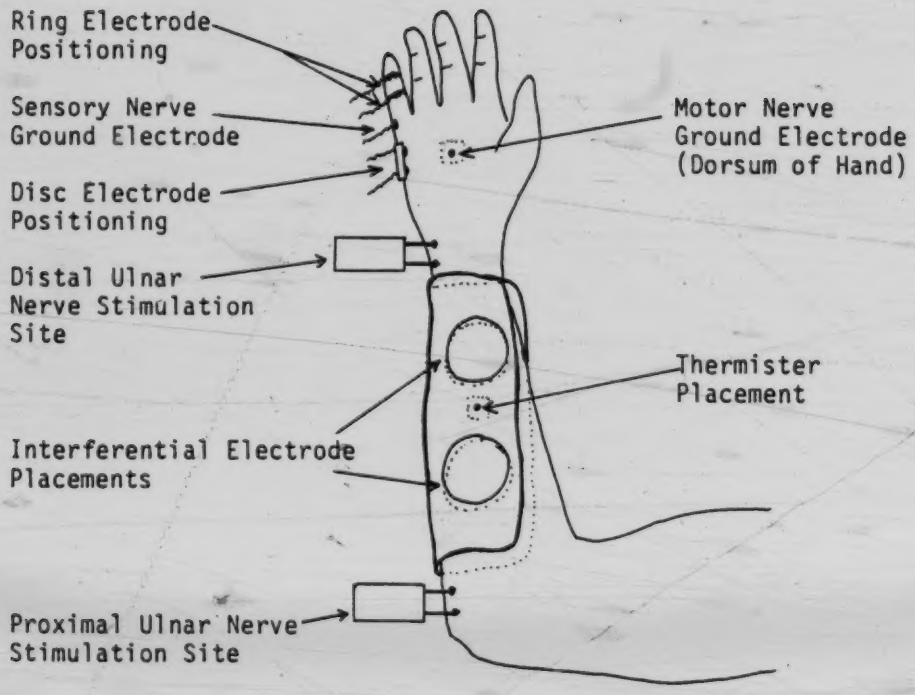
Ring Electrode Positioning
Sensory Nerve Ground Electrode
Disc Electrode Positioning
Distal Ulnar Nerve Stimulation Site
Interferential Electrode Placements
Proximal Ulnar Nerve Stimulation Site
Motor Nerve Ground Electrode (Dorsum of Hand)
Thermister Placement

FIGURE III-1. Electrode placements and stimulation sites on test forearm.

Sensory recording electrodes were the digital ring type. The cathode was positioned around the middle phalanx of the fifth finger, while the anode was positioned around the distal interphalangeal joint of the same finger (Figure III-1). A disc ground electrode, 8mm in diameter, was applied on the ulnar aspect of the fifth finger at the level of the MCP joint. Placement of the sensory electrodes as described allowed sensory nerve conduction to be performed anti-dromically,[11] which is more consistent than orthodromic conduction in producing high amplitude responses for sensory nerves.[12] Motor and sensory electrodes were secured to the skin with adhesive tape.

A cutaneous thermister was taped to the anterior aspect of the forearm between the 2 anterior interferential electrodes. The thermister was secured using a small piece of porous tape. Recordings of the cutaneous temperature of the forearm were made from the digital thermometer at one minute intervals throughout the testing session. A total of 18 temperature recordings were made (see Appendix D).

Two stimulation sites on the forearm were used to obtain motor and sensory latencies (Figure III-1). Using the TE-42 stimulator* and a low stimulating intensity, the proximal stimulation site in the ulnar notch region was explored (cathode applied distally) until the greatest motor and sensory action potentials were elicited. Exact positioning of the cathode was marked with indelible ink. The distal stimulation site was immediately distal to the interferential pad at the point where the greatest motor and sensory action potentials were elicited.

* TECA Corp., Pleasantville, NY 10570, USA

Exact positioning of the cathode was again marked (Figure III-1). The distance between proximal and distal cathode sites was measured using a plastic tape measure. Distances between stimulation sites were used in the calculation of motor and sensory conduction velocities. The mean distance betwen stimulation sites was 21.0 cm ± 1.1 cm.

Prior to recording latencies, a stimulus of supramaximal intensity was delivered at the proximal stimulation site and then at the distal site. A supramaximal response at each site was necessary to ensure that the response of amplitude and latency were constant.[11] Sensory and motor nerve conduction latencies were simultaneously recorded from the electromyograph on to fiber optic direct recording paper. Recordings of the latencies (Figure I-3) were taken first from the proximal stimulation site and then the distal site. Four sets of latencies were taken during each testing session in the following order: 1) two minutes pre-treatment, 2) immediately pre-treatment, 3) immediately post-treatment and, 4) 5 minutes post-treatment. Figure III-2 illustrates the time sequence of events for each testing session.

Sensory and motor latency recordings from the proximal and distal stimulation sites were coded with a number and randomly attached to a sheet of paper. All of the latencies were coded so that the investigator did not know which time period of the testing session the latencies represented. Nerve conduction velocities were calculated using the following formula[11]:

$$\text{Nerve conduction velocity} = \frac{\text{Distance between stimulation sites}}{\text{Proximal latency - Distal latency}}$$

TIME	ACTIVITY
0 - 15 minutes	Subject preparation and electrode placements.
15 - 16 minutes	Nerve conduction latencies recorded
16 - 18 minutes	Rest
18 - 19 minutes	Nerve conduction latencies recorded
19 - 29 minutes	Interferential treatment
29 - 30 minutes	Nerve conduction latencies recorded
30 - 35 minutes	Rest
35 - 36 minutes	Nerve conduction latencies recorded

Total Time: Approximately 36 minutes

FIGURE III-2. Time sequence of testing session.

2. Treatment: A Vectordyne 2* interferential machine was used to administer treatments with one 185 mm square flexible electrode pad containing four circular electrodes, each with a diameter of 60 mm. Each electrode was moistened with tap water. The pad was bent around the ulnar aspect of the forearm such that two electrodes contacted the anterior surface of the forearm and two electrodes contacted the posterior surface. This placement was chosen to position the ulnar nerve between the anterior and posterior electrodes. The base of the electrode pad was positioned 4 cm distal to the olecranon process to allow access to the ulnar notch with the stimulator. The electrode pad was secured on the forearm with a tensor bandage, ensuring that excessive pressure was not applied.

Using the rhythmical mode, a treatment frequency of either 0 to 20 Hz, 80 to 100 Hz, or the control was applied for a duration of ten minutes. The cycle duration was fixed at 20 seconds and the vector sweep was used as suggested in the IFC manufacturer's operating manual.[10] A high intensity stimulus (mean 7.6 mA ± 0.9 mA for 0 - 29 Hz, mean 8.1 mA ± 0.8 mA for 80 - 100 Hz) was delivered to the subject. High intensity stimulus was defined as a strong "pins and needles" sensation felt by the subject, but no strong muscle contraction occurring.[2]

* Medelco Ltd., 4478 Chesswood Drive, Downsview, Ont., M3J 2B9

ETHICAL CONSIDERATIONS

Interferential therapy is a commonly used modality and does not expose subjects to any abnormal physical or mental risks. Additionally, nerve conduction testing is a common investigative procedure and does not involve any risk to the subject.[11] There are only a few contraindications to treatment with interferential therapy which are listed below:

i) active cancer or tuberculosis (in the region being treated)
ii) acute local infections
iii) pregnancy (if treating the lower abdominal area)
iv) large open wounds (in the region being treated)
v) severe cardiac conditions, or presence of pacemaker
vi) severe hypotension or hypertension
vii) dermatological conditions (in the area being treated)
viii) acute and sub-acute thrombo-phlebitis[2,12,60]

The present study was approved by the University of Alberta Department of Physical Therapy's Student Project Ethical and Research Review Committee. All subjects were verbally informed of the testing procedures and all signed consent forms (See Appendix A).

DATA ANALYSIS

A two-way analysis of variance with repeated measures on both factors (interferential frequency and time) was employed to separately examine motor and sensory nerve conduction velocities and cutaneous temperatures.[61] The Tukey test was used to determine which of the trial means were significantly different from each other for cutaneous temperature.[61].

To maximize internal validity, reliability tests were performed for the calculation of motor and sensory nerve conduction velocities[58] (see Appendix D).

CHAPTER IV

RESULTS

Table IV-1 illustrates mean and standard deviation values of sensory and motor nerve conduction velocities (NCV) for each treatment group at various time intervals during the study. The means and standard deviations for skin temperatures are also shown in Table IV-1.

Skin temperatures monitored at one minute time intervals during the various treatments revealed a progressive elevation up to the immediate post-treatment period (see Figure IV-1).

Application of the two-way analysis of variance (with a repeated measures procedure)[61] to the motor and sensory nerve conduction data, showed no statistically significant treatment versus time interaction effect, treatment effect or time effect ($p > 0.05$) (see Tables IV-2 and IV-3). A similar analysis of the temperature values, however, indicated statistically significant differences ($p < 0.05$) for time effects (refer to Table IV-4). No statistically significant treatment versus time interaction effect or treatment effect ($p > 0.05$) was demonstrated for skin temperature values. Summaries of the analyses of variance for motor NCV, sensory NCV and skin temperature are shown in Tables IV-2, IV-3 and IV-4 respectively.

A post hoc Tukey test[61] for temperature time effects revealed statistically significant differences ($p < 0.01$) in mean skin temperatures between the time intervals of two minutes pre-treatment

Table IV-1

Mean and standard deviation nerve conduction traits and skin temperatures at various times pre- and post- treatment with IFC. (n = 18)

		Time of Measurement During Testing			
Treatment		Two minutes pre treatment	Immediately pre treatment	Immediately post treatment	Five Minutes post treatment
Motor NCV (m/s)	Control	61.921 (2.770)	62.172 (2.736)	62.399 (3.298)	61.693 (3.198)
	0-20 Hz	62.195 (4.361)	62.295 (4.078)	61.960 (4.074)	62.094 (4.582)
	80-100 Hz	62.907 (3.344)	62.862 (2.817)	62.952 (3.547)	61.990 (4.096)
Sensory NCV (m/s)	Control	62.624 (3.467)	62.342 (3.640)	62.691 (3.793)	62.168 (3.746)
	0-20 Hz	61.722 (2.567)	61.726 (2.353)	61.646 (3.097)	62.045 (3.412)
	80-100 Hz	63.084 (3.497)	63.283 (3.180)	62.678 (3.876)	62.439 (3.968)
Temp. (^{o}C)	Control	32.6 (0.8)	32.7 (0.7)	33.2 (0.7)	33.3 (0.7)
	0-20 Hz	32.7 (1.2)	32.8 (1.2)	33.2 (1.4)	33.4 (1.2)
	80-100 Hz	32.6 (1.1)	32.8 (1.0)	33.4 (0.9)	33.5 (0.9)
	Time main effect	32.6 (1.0)	32.8 (1.0)	33.3 (1.0)	33.4 (1.0)

(Standard deviation)

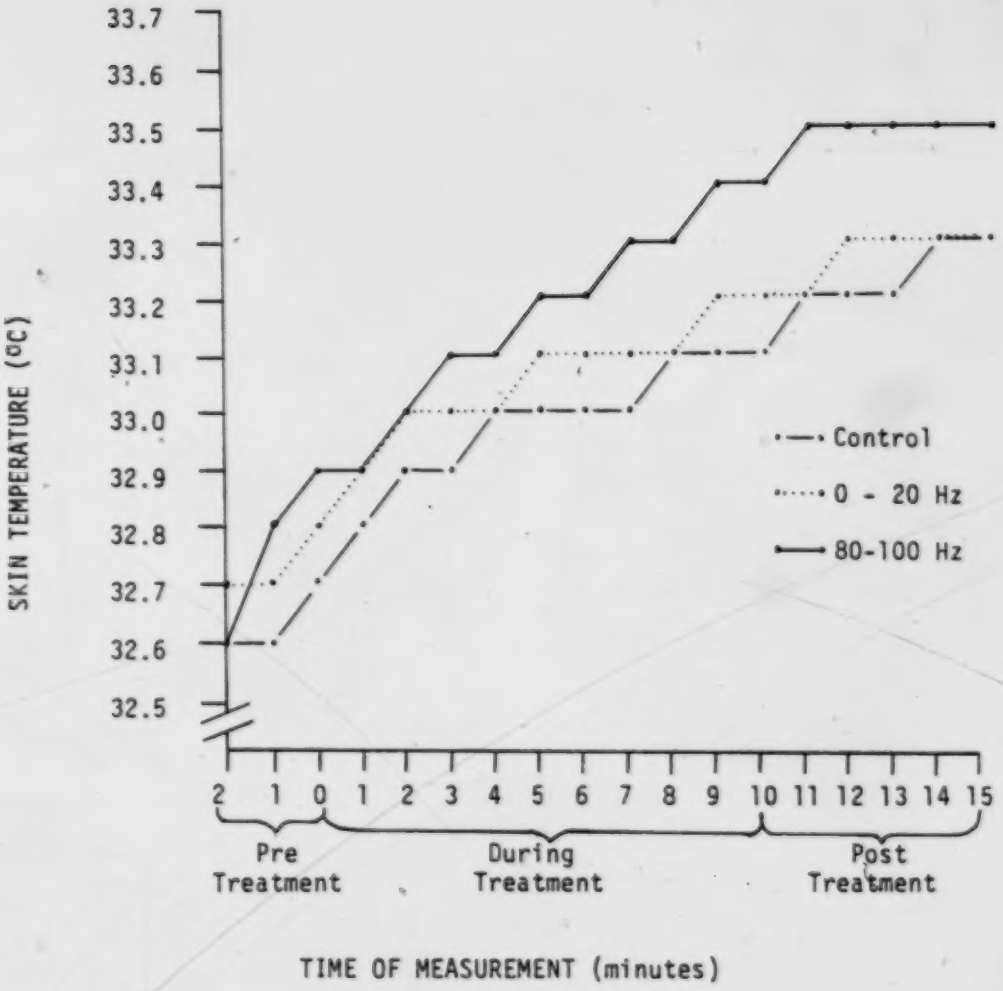

Figure IV-1. Skin temperature at various intervals throughout the experiment. From left to right: 2 to 0 = 2 minutes pre- treatment to immediately pre- treatment, 0 to 10 = treatment period, 10 to 15 = immediately post- treatment to 5 minutes post- treatment.

Table IV-2

ANOVA summary for motor nerve conduction velocities

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F Ratios	F .05 Critical
Treatment main effects	22.532	2	11.266	0.239	3.15
Between subject error	2402.816	51	47.114		
Time main effects	15.487	3	5.162	0.631	2.60
Treatment-time interaction	2.653	6	0.442	0.054	2.10
Within Subject error	1252.271	153	8.185		
TOTAL	3695.759	215			

Table IV-3

ANOVA summary for sensory nerve conduction velocities

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F Ratios	F .05 Critical
Treatment main effects	42.537	2	21.268	0.502	3.15
Between subject error	2162.880	51	42.409		
Time main effects	2.273	3	0.758	0.546	2.60
Treatment-time interaction	13.549	6	2.258	1.592	2.10
Within subject error	216.911	153	1.418		
TOTAL	2438.150	215			

Table IV-4

ANOVA summary for skin temperatures

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F Ratios	F .05 Critical
Treatment main effects	1.0	2	0.5	0.13	3.15
Between subject error	197.1	51	3.9		
Time main effects	21.6	3	7.2	72.0*	2.60
Treatment-time interaction	0.6	6	0.1	1.0	2.10
Within subject error	9.2	153	0.1		
TOTAL	229.5	215			

*Statistically significant at the $p<0.05$ level

and immediately pre-treatment, two minutes pre-treatment and immediately post-treatment, two minutes pre-treatment and five minutes post-treatment, immediately pre-treatment and immediately post-treatment, immediaty pre-treatment and five minutes post-treatment. No statistically significant difference in skin temperature was shown between the interval of immediately post-treatment and five minutes post-treatment (see Table IV-5).

No discomfort attributable to treatment was reported by any of the subjects.

Table IV-5

Post hoc Tukey test - differences between paired means for skin temperatures (^{o}C)

	2 Minutes pre treatment	Immediately pre treatment	Immediately post treatment	5 Minutes post treatment
2 minutes pre treatment	____	0.2*	0.7*	0.8*
Immediately pre treatment	____	____	0.5*	0.6*
Immediately post treatment	____	____	____	0.1
5 Minutes post treatment	____	____	____	____

*Statistically significant at $p < 0.01$ level

CHAPTER V

DISCUSSION

Nerve conduction investigations can provide important information regarding pathology of the nervous system.[53,54] Additionally, nerve conduction studies have proven valuable in determining the effects of various electrical modalities on peripheral nerves.[41,47,52]

Results from the present study indicate that IFC, at frequencies of 0-20 Hz and 80-100 Hz, has no significant effect on sensory or motor nerve conduction velocity ($p > 0.05$). Additionally, no significant relationship between skin temperature changes and changes in sensory or motor NCV was demonstrated in this study ($p > 0.01$).

The lack of any change in motor nerve conduction velocities observed in the present study conflicts with the decreased motor NCV reported by Rehacek et al.[29,30] In those studies, however, different IFC frequency ranges were examined (0-100 Hz and 0-10 Hz), higher IFC intensities of 20 mA ' 2 mA were used and electrode application techniques were different than those used in the present study. From their results, Rehacek et al concluded that rhythmic stimulation by IF currents of 0-10 Hz or 0-100 Hz or 0-100 Hz cause prolonged latency and slower conductivity along peripheral motoneurons.[29,30]

Motor nerve conduction velocity results of the present study are in agreement with those reported by Belcher[4], although Belcher used a different frequency range (0-100 Hz) and the IFC intensity was not specified. The type of electrodes and sites of application used by Belcher[4] also varied from this study.

To date there are no published IFC sensory NCV studies to compare with the results of the present study.

None of the previously reported IFC studies has monitored tissue temperature changes.[4,29,30] Halar et al[62] believe that tissue temperature change is the most significant nonpathologic factor to influence clinical measurement of NCV. Investigators have demonstrated that elevated temperatures cause increased conduction rates and lowered temperatures result in decreased conduction rates.[47,51,63] Halar et al[62] stated that distal extremities may be cooler than core body temperature when an individual is exposed to lower environmental temperatures. In the studies by Rehacek et al[29,30], it is possible that environmental temperatures were cool enough to cause cooling of subject's extremities during testing sessions. Cooling of the tested extremity could account for the reduced motor NC velocities observed in their studies.

Results of the present study revealed significant skin temperature increases as a time main effect ($p < 0.01$). Since there was no statistically significant difference between treatment groups, skin temperatures increases may have resulted from the insulating action of the IC pad and tensor bandage. The electrode pad consisted of rubberized material and was secured around the subjects forearm with a tensor bandage. The pad and tensor may have acted as an insulator, therefore, not allowing normal evaporative cooling of the limb to occur.

Although not statistically significant, the 80-100 Hz group did demonstrate slightly elevated skin temperatures during and following

treatment in comparison with the control and 0-20 Hz treatment groups (Figure IV-1). According to several authors,[2,64,65] IF currents above 80 Hz have an autonomic effect (mainly depression of sympathetic activity). Since the muscular walls of arterioles are supplied by sympathetic nerve fibers, inhibition of sympathetic activity causes decreased tone in the vessel walls resulting in vasodilatation.[23] Vasodilation of the arterioles results in hyperemia[23] and concomitant increased skin temperatures.[23,62] It is possible, therefore, that the elevated skin temperatures observed in the 80-100 Hz treatment group may be partially attributed to depression of sympathetic nerve activity with resultant vasodilatation.

From a review of the literature, there are possible mechanisms of pain relief with IFC, other than that explored in the present study. It is plausible that IFC has similar pain relieving mechanisms to transcutaneous electrical nerve stimulation (TENS). According to De Domenico[6], the pulse duration of IFC is aproximately 125 microseconds and the effective stimulus has a frequency of between 0 and 100 Hz. Although authors have suggested various application methods for TENS, frequently cited specifications for pulse duration vary between 50 and 500 microseconds and frequencies of between 10 and 300 Hz.[16,66,67] The technical specifications of TENS and IFC can be quite similar therefore, although the waveforms of these two modalities differ markedly.

Several commonly cited theories explaining the pain relieving mechanism of TENS include: stimulating the release of endogenous endorphins, and activation of pain-gating mechanisms.[66,67] Endorphins

are endogenous opiates released from the brain which have potent pain reducing potential.[23,67] A study by Salar et al, demonstrated increased beta endorphin levels during and after 20 minutes of treatment with TENS.[68] Future IFC studies could also monitor endorphin levels to determine whether IFC alters the endorphinergic system.

Another frequently cited mode of pain relief for both TENS and IFC is activation of "pain-gating" mechanisms.[2,6,66,67] The "gate-control" theory was first presented by Melzack and Wall in 1965 to explain pain mechanisms.[39] Using the framework of the gating theory, authors have postulated that electrical stimulation from TENS overloads light touch and proprioceptive input to the spinal cord.[66,67] Large diameter afferent A fibers mediate light touch and proprioception, while small diameter afferent C fibers convey nociceptive input.[66] Apparently, by overlapping A fiber activity, inhibitory interneurons are activated which inhibit transmission from small diameter pain fibers. A negative feedback occurs therefore, and the "gate" at the spinal level is "closed", inhibiting nociceptive input from going into the spinal cord.[66,67]

In summary, findings of the present study suggest that pain relief using IFC at frequencies of 0-20 Hz or 80-100 Hz cannot be attributed to altered sensory or motor NC velocities.

CHAPTER VI

CONCLUSION

In the present study, interferential currents applied at frequencies of 0-20 Hz and 80-100 Hz to the forearm for 10 minutes, did not have any significant effect on sensory or motor nerve conduction velocity. It would appear from these findings, therefore, that the pain relieving action of interferential currents is not due to decreased conduction velocities of sensory or motor nerves.

In this study, skin temperatures increased significantly over time. This finding was attributed to the insulating action of the interferential pad and tensor bandage.

It is evident from the results of the present study and a review of the literature that further investigations are necessary to determine the pain-relieving mechanism associated with interferential treatments.

Future research regarding interferential currents might include monitoring the levels of endogenous opiates such as endorphins, before, during and following treatment with interferential currents. Further nerve conduction studies could be performed using nerves more superficial than the ulnar nerve in the forearm, which was examined in the present study. Additionally, variations of IFC treatment such as increased treatment time, various frequency ranges and electrode pad shapes and sizes should also be examined. Finally, in order that interferential therapy become a less empirical treatment, well designed clinical studies are needed.

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APPENDIX A

INFORMED CONSENT FORMS

FACULTY OF REHABILITATION MEDICINE

DEPARTMENT OF PHYSICAL THERAPY

UNIVERSITY OF ALBERTA

INFORMED CONSENT FORM FOR INVESTIGATIVE STUDY

Effects of Interferential Currents On Nerve Conduction Velocity

Outline of Procedures (retained by subject)

Interferential current is a relatively common physiotherapeutic modality which produces a low frequency current within the body. This modality is frequently used to relieve pain, yet little is known about how this occurs. The purpose of the present study is to examine the effects of interferential currents on nerve conduction. It is hoped this information will provide further insight into the pain relieving properties of interferential current therapy.

The entire procedure will require approximately two hours over 3 separate testing sessions (approximately 35 minutes each session). The first session you will be assigned to a treatment frequency. During one testing session you will receive no interferential treatment, however, recordings will still be taken. Recording electrodes will be placed along the surface of your little finger and attached with adhesive tape. The interferential electrode pad will then be secured along the inner aspect of your forearm. Two points of stimulation will be marked, one at the elbow and the other close to the wrist. Two nerve conduction velocities will be recorded prior to the treatment and two

following treatment.

On completion of the testing procedure, all electrodes and adhesive tape will be removed and your forearm wiped clean.

All records will be held in confidence. You have the right to withdraw from participation at any time. In the event that questions concerning the study arise, please feel free to contact:
Laurie Freebairn at 434-9887.

Faculty of Rehabilitation Medicine University of Alberta

Department of Physical Therapy

INFORMED CONSENT FORM FOR INVESTIGATIVE STUDY

Effects of Interferential Currents on Nerve Conduction Velocity

Subject Consent (Retained by Investigator)

I _____ do hereby agree to participate as a
(please print name)

subject in the study entitled "Effects of Interferential Currents on Nerve Conduction Velocity" to be conducted by Laurie Freebairn. The nature of this study has been explained to me and I understand the test procedures that I will perform. I also understand that this is not a therapeutic treatment. I have been advised that I may withdraw from participation at any time.

_____ _____
Subject's Signature Date

_____ _____
Subject's Address Phone No.

I hereby certify that I was a witness during the explanation referred to above and to the signature.

_____ _____
Witness's Signature Date

APPENDIX B

CALIBRATION OF EQUIPMENT

Calibration of the Interferential Machine

The Vectordyne II Interferential Current Therapy Unit* was not capable of being calibrated. The frequency output of the machine was therefore confirmed using a Multi Counter+ frequency counter. The frequencies of 0-20 Hz and 80-100 Hz which were used in the present study, were checked with a frequency counter in intervals of 5 Hz. The data is displayed in Table A-1.

Calibration of the Electromyograph

In order to verify the sweep speed of the TECA EMG**, a monophasic square wave pulse of 1 ms duration from a Tektronix++ storage oscilloscope was displayed onto the TECA oscilloscope. Traces were obtained onto photographic paper. These were then analyzed to ensure accuracy of the TECA EMG. No calibration was necessary.

Calibration of the Digital Thermometer

A Fisher Oven*+ (0.7 cubic feet, 800 watts) and a Propper chemical thermometer+* were used for calibrating the digital thermometer***. The chemical thermometer and digital thermister were inserted into the middle hole of the oven ensuring that the thermister did not touch the

* Medelco Ltd, 4478 Chesswood Drive, Downsview Ont., M3J 2B9

\+ John Fluke Manufacturing Co. Ltd., 2247 Midland Ave., Scarborough Ont.

** TECA Corp., Pleasantville, NY 10570, USA

++ Model 5441 Storage Oscilloscope, Beaverton, Oregon, USA

*+ Fisher Oven, Fisher Scientific Co.

+* Propper Mfg Co. Inc., LIC, NY 11101, USA

***YSI Model 49TA Digital Thermometer, Yellow Springs Instrument Co., Yellow Springs, OH 45387, USA

chemical thermometer. The thermister wire and chemial thermometer were secured to the oven with tape and the remaining holes in the oven were plugged with cork. The oven was then heated to a temperature of slightly above 43°C on the chemical thermometer since this is the highest temperature the digital thermometer will record. The oven was then turned off and when the digital thermometer recorded 43°C, the temperature on the chemical thermometer was recorded. As temperatures decreased in 0.5°C intervals on the chemical thermometer, the corresponding temperature reading on the digital thermometer was recorded. This procedure continued until a temperature of 27°C was recorded on the chemical thermometer, a temperature well below that anticipated to occur during the study. Temperatures were converted by means of standard linear regression (See converted values in Table A-2).

TABLE A-1.

Evaluation of the IFC machine frequency output.

IFC CIRCUIT MONITORED*	FREQUENCY COUNTER READING+	IFC SETTING**	ACTUAL IFC FREQUENCY OUTPUT++
Circuit 1 (Red)	4095 Hz	5 Hz	5 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4100 Hz	10 Hz	10 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4105 Hz	15 Hz	15 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4111 Hz	20 Hz	21 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4171 Hz	80 Hz	81 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4176 Hz	85 Hz	86 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4181 Hz	90 Hz	91 Hz
Circuit 2 (White)	4090 Hz		
Circuit 1 (Red)	4186 Hz	95 Hz	96 Hz
Circuit 2 (White)	4090 Hz		

* IFC circuit monitored from Vectordyne 2 IFC machine

\+ Actual reading from frequency counter

** Actual setting on Vectordyne 2 IFC machine

\+\+ Actual IFC frequency output (Circuit 1 - Circuit 2)

CALIBRATION OF THE DIGITAL THERMOMETER

Temperature Recorded From Chemical Thermometer (°C)	Temperature Recorded From Digital Thermometer (°C)
43.0	40.7
42.5	40.3
42.0	40.8
41.5	40.4
41.0	40.0
40.5	39.5
40.0	38.9
39.5	38.3
39.0	37.8
38.5	37.5
38.0	36.9
37.5	36.4
37.0	35.8
36.5	35.4
36.0	34.7
35.5	34.3
35.0	33.8
34.5	33.0
34.0	32.5
33.5	31.9
33.0	31.3
32.5	30.8
32.0	30.3
31.5	29.8
31.0	29.4
30.5	28.9
30.0	28.5
29.5	27.9
29.0	27.6
28.5	26.9
28.0	26.4
27.5	25.8

CONVERTED TEMPERATURE VALUES, CALCULATED BY STANDARD LINEAR REGRESSION.

Digital Thermometer Temperatures	Converted Temperature Values	Digital Thermometer Temperatures	Converted Temperature Values
34.0 °C	35.6 °C	30.7°C	32.3 °C
33.9	35.5	30.6	32.2
33.8	35.4	30.5	32.1
33.7	35.3	30.4	32.0
33.6	35.2	30.3	31.9
33.5	35.1	30.2	31.8
33.4	35.0	30.1	31.7
33.3	34.9	30.0	31.6
33.2	34.8	29.9	31.5
33.1	34.7	29.8	31.4
33.0	34.6	29.7	31.3
32.9	34.5	29.6	31.2
32.8	34.4	29.5	31.1
32.7	34.3	29.4	31.0
32.6	34.2	29.3	30.9
32.5	34.1	29.2	30.8
32.4	34.0	29.1	30.7
32.3	33.9	29.0	30.6
32.2	33.8	28.9	30.5
32.1	33.7	28.8	30.4
32.0	33.6	28.7	30.3
31.9	33.5	28.6	30.2
31.8	33.4	28.5	30.1
31.7	33.3	28.4	30.0
31.6	33.2	28.3	29.9
31.5	33.1	28.2	29.8
31.4	33.0	28.1	29.7
31.3	32.9	28.0	29.6
31.2	32.8	27.9	29.5
31.1	32.7	27.8	29.4
31.0	32.6	27.7	29.3
30.9	32.5	27.6	29.2
30.8	32.4	27.5	29.1

APPENDIX C

RELIABILITY STUDY

RELIABILITY

The reliability of the experimenter in accurately and consistently calculating motor and sensory nerve conduction velocities was calculated as follows. Two stimulation sites were marked on the forearm of a subject. Ten recordings with supramaximal stimulation at each site were recorded onto photographic paper. These 20 recordings were then coded and mixed. Lines were drawn on all recordings before calculation of latencies. Motor and sensory conduction velocities were then calculated for each recording. Percent error was then calculated separately for motor and sensory conduction velocities. Percent error for motor conduction velocity was 1.20%, and for sensory conduction velocity 1.50%.

APPENDIX D

DATA ACQUISITION FORMS

Individual Data Acquisition

Name _____ Date _____ Time _____

Treatment Sequence _____ Session Number _____

	Latencies		Time	NCV	Change
	Proximal	Distal			
2 Minutes Pre Rx					
Pre Rx					
MOTOR					
Post Rx					
2 Minutes Post Rx					
2 Minutes Pre Rx					
Pre Rx					
SENSORY					
Post Rx					
5 Minutes Post Rx					

IFC Frequence _____ Hz Intensity ____ mA

Distance between stimulation sites _____ cm

Amplifier setting _____ Frequency cutoffs _____

Individual Temperature Data

Name _____ Age _____

Date _____ Time _____

Treatment Sequence _____ Session Number _____

TIME (minutes)	SKIN TEMPERATURE (^{o}C)	TIME (minutes)	ROOM TEMPERATURES (^{o}C)
2 Pre		5 Pre	
1		5 Post	
0 Pre			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11 (Post)			
12			
13			
14			
15			

IFC Frequency _____Hz IFC Intensity _____mA

ORAL QUESTIONNAIRE FOR SCREENING POTENTIAL SUBJECTS

Have you had, or do you have any of the following medical conditions:

1. Damage to the ulnar nerve in your dominant arm
2. Previous elbow injury of your dominant arm (fracture or dislocation)
3. Diseases of the nervous system
4. Active cancer or tuberculosis
5. Acute local infections
6. Pregnancy
7. Large open wounds in the region being treated
8. Severe cardiac conditions or have a pacemaker
9. Severe hypotension or hypertension
10. Dermatological conditions in the area being treated
11. Actue or sub-acute thrombo-phlebitis

APPENDIX E

RAW DATA

MOTOR NERVE CONDUCTION VELOCITIES (m/sec)
CONTROL GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	57.862	57.862	58.599	55.090
2	56.815	55.750	55.062	57.179
3	64.545	63.582	64.060	64.060
4	63.880	62.482	63.407	60.282
5	61.408	61.844	62.286	62.286
6	65.785	68.785	69.824	68.034
7	60.952	60.540	61.793	60.540
8	61.630	61.630	59.856	62.090
9	59.130	62.290	62.769	63.256
10	61.259	61.259	60.414	58.792
11	58.873	58.873	58.873	58.873
12	62.424	64.375	66.452	61.955
13	64.496	63.511	64.000	63.030
14	65.600	66.129	65.079	67.213
15	60.148	61.985	61.053	61.053
16	63.125	64.127	63.622	61.679
17	66.016	65.484	64.444	64.444
18	60.625	61.587	61.587	60.625

MOTOR NERVE CONDUCTION VELOCITIES (m/sec)
0 - 20 Hz GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	56.250	58.064	58.824	55.901
2	55.854	57.000	55.854	54.940
3	66.154	64.179	61.870	62.319
4	57.178	57.888	58.987	58.616
5	65.454	64.962	64.962	64.478
6	64.194	68.034	69.217	68.621
7	64.818	64.818	66.269	64.818
8	65.846	64.848	64.361	64.848
9	62.256	61.333	62.727	67.317
10	59.549	58.667	58.667	56.170
11	57.778	58.543	56.667	57.778
12	65.484	66.557	65.484	64.444
13	69.000	68.300	64.186	66.240
14	62.946	62.462	62.946	60.597
15	55.000	55.000	55.000	56.170
16	63.492	62.016	62.500	61.538
17	67.800	66.227	67.227	68.966
18	60.465	61.417	59.542	63.934

MOTOR NERVE CONDUCTION VELOCITIES (m/sec)
80 - 100 Hz GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	57.284	58.734	57.284	53.028
2	59.060	57.895	60.274	57.895
3	63.333	65.312	65.827	62.857
4	62.819	61.579	63.243	61.176
5	65.538	65.538	66.046	64.060
6	69.734	66.780	69.734	69.123
7	61.408	65.075	63.650	64.592
8	58.889	59.718	58.082	54.710
9	58.507	60.775	62.222	62.222
10	60.597	59.706	58.000	60.148
11	65.758	61.560	63.824	62.000
12	64.688	63.692	61.791	60.882
13	65.454	65.454	64.390	67.119
14	62.769	64.252	62.769	63.256
15	61.791	62.256	58.310	59.143
16	64.567	65.079	64.567	63.077
17	67.869	66.774	68.429	67.317
18	62.256	61.333	64.688	63.206

SENSORY NERVE CONDUCTION VELOCITIES (m/sec)
CONTROL GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	59.740	58.974	60.131	58.599
2	58.684	57.548	58.684	57.922
3	60.426	59.580	60.000	60.000
4	67.936	65.344	65.344	66.875
5	57.368	58.523	58.523	59.320
6	62.188	61.705	63.680	62.188
7	62.222	62.222	62.222	60.540
8	61.176	57.778	59.856	58.182
9	60.444	60.000	63.256	63.750
10	58.400	59.189	56.883	55.443
11	62.388	63.333	62.388	61.470
12	70.427	71.034	73.571	69.830
13	66.032	66.560	66.032	67.097
14	66.129	66.667	65.079	66.129
15	62.946	61.985	61.515	61.515
16	65.691	65.161	65.691	64.640
17	62.946	62.946	61.985	62.946
18	62.080	63.606	63.606	62.581

SENSORY NERVE CONDUCTION VELOCITIES (m/sec)
0 - 20 Hz GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	61.224	62.067	57.325	60.811
2	56.646	58.462	55.273	54.940
3	60.140	58.904	59.722	59.310
4	62.133	61.316	63.401	64.722
5	61.714	61.714	62.158	62.158
6	60.303	61.705	63.680	65.246
7	64.348	63.885	65.294	64.348
8	62.482	62.941	62.482	62.941
9	61.333	60.000	61.333	63.692
10	59.549	60.923	60.458	57.810
11	60.136	60.966	60.136	59.329
12	67.107	67.667	68.235	69.402
13	65.714	64.688	62.727	63.206
14	63.937	62.462	63.937	62.946
15	57.810	57.391	56.978	57.391
16	62.500	62.500	61.538	61.538
17	62.500	61.069	61.582	62.069
18	61.417	62.400	63.415	65.000

SENSORY NERVE CONDUCTION VELOCITIES (m/sec)
80 - 100 Hz GROUP

Subject No.	2 Minutes Pre Treatment	Immediately Pre Treatment	Immediately Post Treatment	5 Minutes Post Rx
1	61.053	62.282	61.457	61.053
2	61.538	60.690	61.638	59.864
3	58.873	59.714	59.291	58.056
4	61.579	61.987	62.400	61.176
5	63.582	62.647	60.857	60.000
6	70.357	69.734	70.357	72.294
7	61.844	63.650	64.118	63.650
8	59.301	56.913	54.359	54.013
9	59.847	63.740	60.775	62.222
10	57.183	59.270	56.389	58.417
11	63.358	62.000	66.260	63.824
12	69.000	66.774	65.197	65.197
13	62.857	64.918	62.857	63.871
14	64.762	66.341	64.762	65.806
15	65.197	64.688	62.256	60.882
16	67.768	67.213	66.129	66.129
17	62.727	61.333	61.333	62.256
18	64.688	65.197	67.869	65.197

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER CONTROL GROUP

Minutes	Subject Number 1	2	3	4	5	6	7	8	9
2 Pre*	32.1	31.6	32.5	32.4	33.2	33.0	31.4	33.9	31.9
1 Pre	32.1	31.6	32.6	32.5	33.2	33.1	31.5	34.0	32.0
0 Pre+	32.2	31.6	32.7	32.6	33.2	33.2	31.6	34.0	32.1
1	32.3	31.7	32.8	32.7	33.2	33.3	31.6	34.0	32.2
2	32.3	21.7	32.9	32.7	33.3	33.4	31.8	34.1	32.4
3	32.3	31.7	33.0	32.7	33.3	33.5	31.9	34.1	32.5
4	32.3	31.7	33.1	32.8	33.4	33.5	31.9	34.1	32.6
5	32.4	21.7	33.2	32.8	33.5	33.6	32.0	34.1	32.7
6	32.3	31.7	33.2	32.8	33.5	33.7	32.0	34.1	32.8
7	32.3	31.7	33.3	32.8	33.5	33.7	32.0	34.1	32.8
8	32.5	31.7	33.3	32.8	33.5	33.8	32.1	34.1	32.9
9	32.5	31.7	33.4	32.8	33.5	33.8	33.2	34.1	33.0
10	32.5	31.7	33.4	32.8	33.5	33.9	32.2	34.1	33.0
11 Post**	32.5	31.7	33.5	32.8	33.7	33.9	32.3	34.2	33.1
12	32.5	31.7	33.6	32.9	33.7	33.9	32.3	34.2	33.2
13	32.5	31.7	33.6	32.9	33.8	33.9	32.3	34.2	33.2
14	32.5	31.7	33.6	32.9	33.8	34.0	32.3	34.2	33.3
15	32.5	31.7	33.6	32.9	33.8	34.0	32.3	34.2	33.3

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post-treatment

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER
CONTROL GROUP

Minutes	Subject Number 10	11	12	13	14	15	16	17	18
2 Pre*	32.6	32.2	33.9	32.1	33.8	32.0	33.1	32.7	32.0
1 Pre	32.7	32.3	33.9	32.2	33.9	32.1	33.2	32.7	32.1
0 Pre+	32.8	32.3	33.9	32.3	34.0	32.2	33.3	32.7	32.0
1	32.8	32.5	33.9	32.4	34.1	32.3	33.3	32.9	32.2
2	33.0	32.5	33.9	32.4	34.1	32.4	33.4	33.0	32.3
3	33.0	32.5	33.9	32.5	34.2	32.5	33.4	33.0	32.4
4	33.1	32.6	33.9	32.5	34.2	32.6	33.5	33.1	32.4
5	33.1	32.6	33.9	32.5	34.2	32.7	33.5	33.1	32.5
6	33.2	32.6	33.9	32.6	34.3	32.7	33.6	33.1	32.5
7	33.2	32.7	33.9	32.6	34.3	32.8	33.6	33.1	32.5
8	33.3	32.7	33.9	32.6	34.4	32.8	33.7	33.2	32.6
9	33.3	32.7	33.9	32.6	34.4	32.9	33.7	33.2	32.6
10	33.3	32.7	33.9	32.7	34.4	32.9	33.7	33.3	32.6
11 Post**	33.4	32.7	33.8	32.7	34.5	33.0	33.7	33.3	32.7
12	33.4	32.8	33.8	32.7	34.5	33.1	33.7	33.3	32.7
13	33.4	32.8	33.8	32.7	34.6	33.1	33.7	33.3	32.7
14	33.4	32.8	33.8	32.8	34.6	33.1	33.7	33.3	32.8
15	33.4	32.9	33.8	32.8	34.6	33.1	33.7	33.4	32.8

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post-treatment

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER
0 - 20 Hz GROUP

	Subject Number								
Minutes	1	2	3	4	5	6	7	8	9
2 Pre*	33.6	29.0	32.1	31.6	32.8	33.9	32.5	33.8	33.1
1 Pre	33.7	29.0	32.2	31.8	32.8	34.0	32.6	33.8	33.2
0 Pre+	33.7	29.0	32.3	31.8	32.9	34.0	32.7	33.9	33.3
1	33.7	29.0	32.3	31.8	33.0	34.0	32.7	34.0	33.4
2	33.7	29.0	32.4	32.0	33.0	34.0	32.8	34.1	33.5
3	33.7	29.0	32.4	32.1	33.1	34.0	32.8	34.2	33.5
4	33.7	28.9	32.5	32.2	33.1	34.0	32.9	34.2	33.6
5	33.8	28.9	32.5	32.3	33.2	34.0	33.0	34.3	33.7
6	33.8	28.8	32.5	32.4	33.2	34.0	33.0	34.3	33.7
7	33.8	28.8	32.6	32.4	33.3	34.0	33.1	34.3	33.8
8	33.8	28.8	32.6	32.5	33.3	33.9	33.2	34.4	33.8
9	33.8	28.8	32.6	32.6	33.3	33.9	33.3	34.4	33.9
10	33.8	28.8	32.6	32.8	33.3	33.9	33.3	34.4	33.9
11 Post**	33.9	28.8	32.7	32.8	33.3	33.9	33.4	34.4	34.0
12	33.9	28.8	32.7	32.8	33.3	33.9	33.4	34.5	34.0
13	33.9	28.8	32.7	32.9	33.3	33.9	33.5	34.5	34.0
14	33.9	28.8	32.8	32.9	33.3	33.9	33.5	34.5	34.0
15	34.0	28.9	32.8	33.0	33.3	33.9	33.5	34.5	34.1

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post-treatment

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER
0 - 20 Hz GROUP

Minutes	Subject Number 10	11	12	13	14	15	16	17	18
2 Pre*	33.2	32.2	34.0	32.5	33.5	31.9	32.9	33.0	32.3
1 Pre	33.3	32.4	34.0	32.6	33.6	31.9	33.0	33.1	32.4
0 Pre+	33.4	32.5	34.0	32.7	33.7	32.0	33.1	33.2	32.5
1	33.4	32.6	34.0	32.8	33.8	32.0	33.1	33.6	33.1
2	33.5	32.7	34.1	32.9	33.8	32.1	33.2	33.7	33.2
3	33.5	32.8	34.2	33.0	33.8	32.1	33.3	33.8	33.2
4	33.5	32.8	34.2	33.0	33.8	32.2	33.3	33.8	33.3
5	33.5	32.8	34.2	33.0	33.8	32.2	33.4	33.8	33.3
6	33.5	32.8	34.2	33.0	33.8	32.3	33.5	33.9	33.3
7	33.5	32.9	34.3	33.1	33.8	32.3	33.5	33.9	33.3
8	33.5	32.9	34.3	33.1	33.8	32.4	33.5	34.0	33.4
9	33.5	33.0	34.3	33.2	33.8	32.4	33.6	34.0	33.5
10	33.6	33.0	34.3	33.2	33.9	32.4	33.6	34.0	33.5
11 Post**	33.7	33.1	34.3	33.3	33.9	32.5	33.7	34.2	33.6
12	33.7	33.1	34.3	33.3	34.0	32.5	33.7	34.2	33.7
13	33.7	33.1	34.3	33.3	34.0	32.6	33.7	34.3	33.7
14	33.7	33.1	34.3	33.3	34.0	32.6	33.7	34.3	33.7
15	33.7	33.1	34.3	33.3	34.0	32.6	33.7	34.3	33.7

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post-treatment

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER
80 - 100 Hz GROUP

	Subject Number								
Minutes	10	11	12	13	14	15	16	17	18
2 Pre*	32.3	33.8	32.0	31.8	34.2	31.8	33.0	32.6	33.5
1 Pre	32.3	33.8	32.2	31.9	34.2	31.9	33.2	32.7	33.6
0 Pre+	32.4	33.8	32.3	32.0	34.3	32.0	33.3	32.8	33.6
1	32.4	33.9	32.4	32.0	34.3	32.1	33.4	33.0	33.7
2	32.5	33.9	32.6	32.1	34.4	32.2	33.4	33.2	33.7
3	32.6	33.9	32.7	32.2	34.4	32.3	33.4	33.3	33.8
4	32.6	33.9	32.8	32.2	34.4	32.3	33.5	33.3	33.8
5	32.7	33.9	32.8	32.3	34.5	32.4	33.5	33.4	33.8
6	32.7	33.9	32.9	32.4	34.5	32.5	33.6	33.5	33.8
7	32.7	34.0	33.0	32.4	34.5	32.6	33.6	33.6	33.9
8	32.7	34.0	33.0	32.5	34.6	32.7	33.7	33.7	33.9
9	32.8	34.1	33.0	32.5	34.6	32.8	33.7	33.8	33.9
10	32.8	34.1	33.0	32.6	34.6	32.9	33.7	33.9	33.9
11 Post**	32.8	34.2	33.1	32.6	34.7	32.9	33.8	34.0	34.0
12	32.8	34.3	33.1	32.7	34.7	32.9	33.8	34.0	34.1
13	32.8	34.3	33.2	32.7	34.7	33.0	33.8	34.1	34.1
14	32.8	34.4	33.2	32.7	34.8	33.0	33.8	34.1	34.1
15	32.8	34.4	33.2	32.7	34.8	33.0	33.8	34.1	34.1

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post treatment

SKIN TEMPERATURES (^{o}C) RECORDED FROM DIGITAL THERMOMETER
80 - 100 Hz GROUP

Minutes	Subject Number 1	2	3	4	5	6	7	8	9
2 Pre*	32.2	32.3	32.6	29.7	33.2	34.5	32.0	32.1	34.1
1 Pre	32.2	32.3	32.8	30.4	33.2	34.6	32.0	32.2	34.2
0 Pre+	32.2	32.4	32.9	31.0	33.3	34.6	32.1	32.3	34.3
1	32.2	32.4	33.0	31.0	33.4	34.7	32.2	32.4	34.3
2	32.2	32.4	33.1	31.1	33.5	34.7	32.3	32.4	34.3
3	32.2	32.5	33.2	31.2	33.5	34.8	32.4	32.5	34.3
4	32.2	32.5	33.2	31.3	33.5	34.8	32.6	32.6	34.3
5	32.2	32.6	33.2	31.3	33.5	34.9	32.7	32.7	34.3
6	2.2	32.6	33.3	31.4	33.6	34.9	32.8	32.8	34.4
7	32.2	32.7	33.3	31.5	33.6	35.0	32.9	32.9	34.4
8	32.2	32.8	33.4	31.6	33.6	35.0	32.9	32.9	34.4
9	32.2	32.8	33.4	31.7	33.6	35.1	33.0	32.9	34.4
10	32.2	32.9	33.5	31.9	33.7	35.1	33.0	32.9	34.4
11 Post**	32.2	33.1	33.5	32.0	33.8	35.2	33.1	32.9	34.4
12	32.2	33.1	33.5	32.0	33.8	35.3	33.1	32.9	34.4
13	32.2	33.1	33.6	32.0	33.8	35.3	33.2	32.9	34.4
14	32.2	33.1	33.6	32.0	33.8	35.4	33.3	32.9	34.4
15	32.2	33.1	33.6	32.0	33.8	35.4	33.3	32.9	34.4

* Pre indicates pre-treatment
\+ 0 Pre indicates immediately pre-treatment
** Post indicates post-treatment

INTERFERENTIAL CURRENT INTENSITIES (mA)

0 - 20 Hz GROUP		80 - 100 Hz GROUP	
Subject Number	Current Intensity	Subject Number	Current Intensity
1	8.0	1	8.0
2	8.0	2	9.0
3	8.0	3	10.0
4	6.0	4	7.5
5	9.0	5	8.5
6	7.5	6	7.5
7	8.5	7	9.5
8	8.0	8	8.5
9	8.0	9	8.0
10	7.0	10	8.0
11	7.5	11	7.5
12	7.0	12	8.5
13	7.0	13	7.0
14	7.0	14	8.0
15	8.5	15	8.0
16	5.5	16	7.0
17	8.0	17	8.0
18	7.5	18	8.0